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BY

OLIVER W. KEENER

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METHOD AND COST OF MINING AT BARR MINE TRI-STATE ZINC AND LEAD DISTRICT [1]

By Oliver W. Keenor[2]

INTRODUCTION

The operation described herein differs from the usual practice in the Tri-State district in two important respects: (1) The ore is loaded into cars which are trammed to the shaft and hoisted on self-dumping cages, and (2) about 30 per cent of the ore is loaded by power shovels. The four-month period covered by the cost data appended at the end of the paper immediately followed a period of about one year during which the mine was shut down, and the expense incident to the resumption of operations is reflected in the costs.

The author acknowledges the assistance of C. F. Jackson, mining engineer, U. S. Bureau of Mines, in the preparation of this paper and the compilation of the data.

HISTORY

The lease to the mine, which is located on a 60-acre tract, was acquired in September, 1916, and exploration by churn drilling was begun almost immediately afterward. The first shaft was sunk as the mill shaft in 1917, and production began in that year. Since the beginning of operations there have been several idle periods; the last resumption of operations was in January, 1929.

GEOLOGY AND ORE DEPOSITS

The ore bodies of this mine are located about the flanks of a huge lime dome. That section of the mine south of No. 2 shaft occurs in massive flint 150 feet thick, which has an overburden of Cherokee shale and Chester sand. The ore minerals occur in brecciated zones as irregular seams cementing fractures in the flint and as masses filling vugs and cavities. The ore minerals consist of sphalerite and some galena, associated with calcite and a highly silicious lime. This massive structure about the Grand Falls chert horizon extends downward to the 300-foot level and was more or less mineralized throughout its entire mass. This was formerly mined on three levels in the richest horizons. The two upper levels are not being worked at present and are practically mined out.

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[2] One of the consulting engineers, U. S. Bureau of Mines.

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The bottom of the ore now being mined lies at a depth of approximately 30 feet below the surface and ranges in thickness from 15 to 87 feet, averaging abou 45 feet. The ore is flat lying but has a slight dip to the north which carries the ore in the north section of the property to a depth of about 40 feet below th main shaft level which is at 300 feet. At this point the ore merges unconformabl with the Grand Falls chert without an appreciable line of demarkation.

In plan the ore bodies are very irregular, but are practically continuous for a distance of about 2,000 feet, measured in a curved line around the flanks o the dome. The width of the ore varies greatly, however, and in places splits int several channels or troughs with barren areas between them. In some places the ore is only 15 to 25 feet wide, while in others it attains widths of over 300 fee Figure 1 is a plan of the mine workings showing the stopes and extent of the ore bodies; Figure 2, A and B, shows cross sections of stopes in active areas.

Above the ore in most parts of the mine is a firm, uniform limestone from which the ore breaks free, leaving a fairly smooth and even roof. The system of fractures in which the ore bodies occur and which has governed the deposition of the ore passes into the roof as well, but is less pronounced there than in the or horizon itself.

PROSPECTING AND EXPLORATION

The 60-acre tract upon which this mine is located has been prospected by 205 churn-drill holes. The first drilling is laid out in rows of holes spaced at more or less regular intervals across the property and drilled primarily to locate the low spots in the structure where the ore is localized in this district. This drilling is followed by closer drilling where good ore or favorable conditio warrant.

No samples are taken after mining operations are started to determine the extent of the ore bodies. Estimates are made after a sufficient number of churn-drill holes are drilled into an ore body to prove it up and prior to beginning mining operations.

The drill cuttings are carefully preserved and logged, and such samples as show as much as 1 per cent of ZnS and PbS are assayed. From a careful analys of these assays an ore body is blocked out. An estimate is then made of the tonnage available and the probable extraction. Experience has proved that these estimates are lower than actual mill tests run.

Figure 3, shows a number of drill holes and an ore body sketched in. Th following is the method of ore estimation used:

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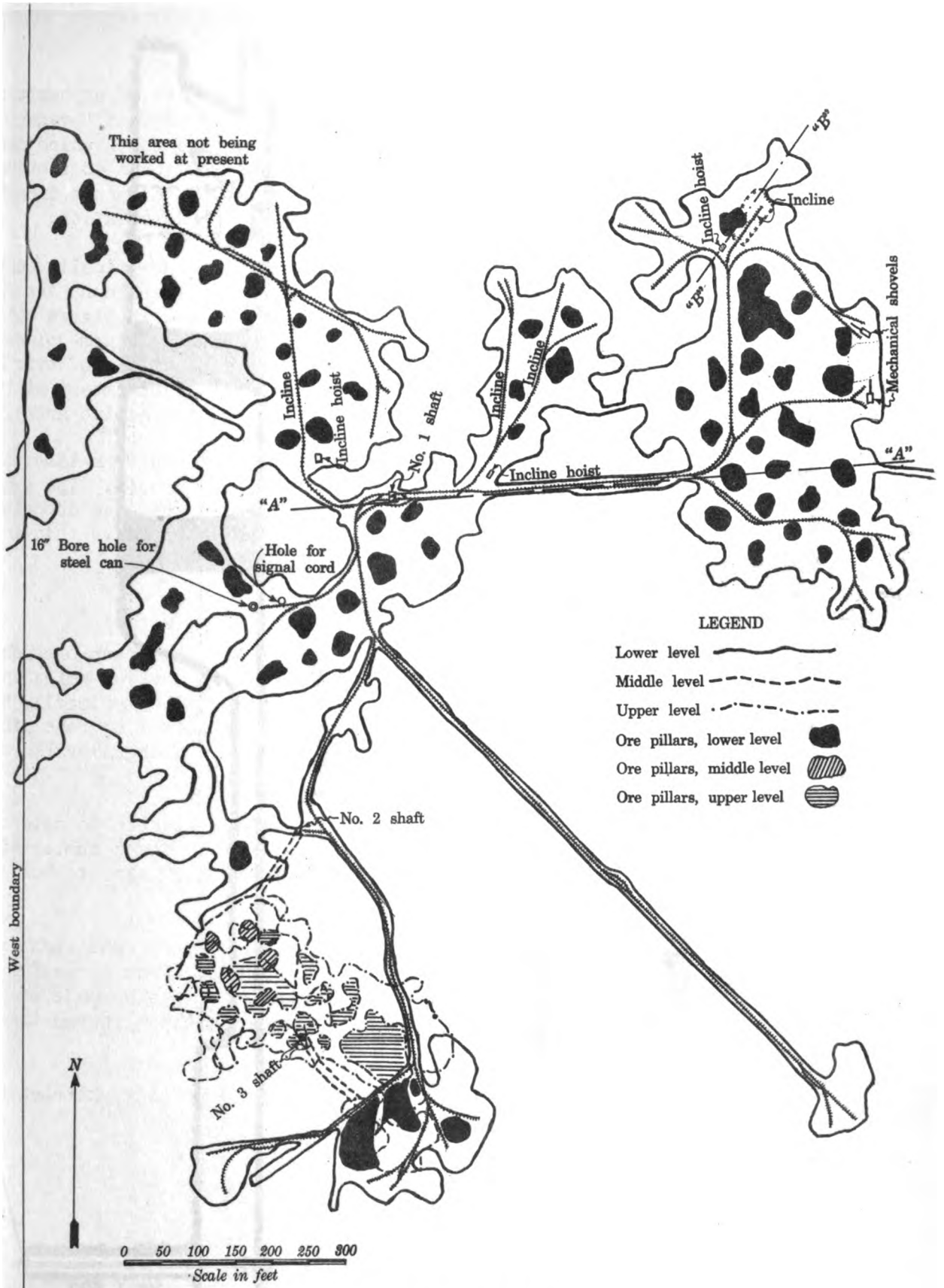

Figure 1.– Plan of Barr mine

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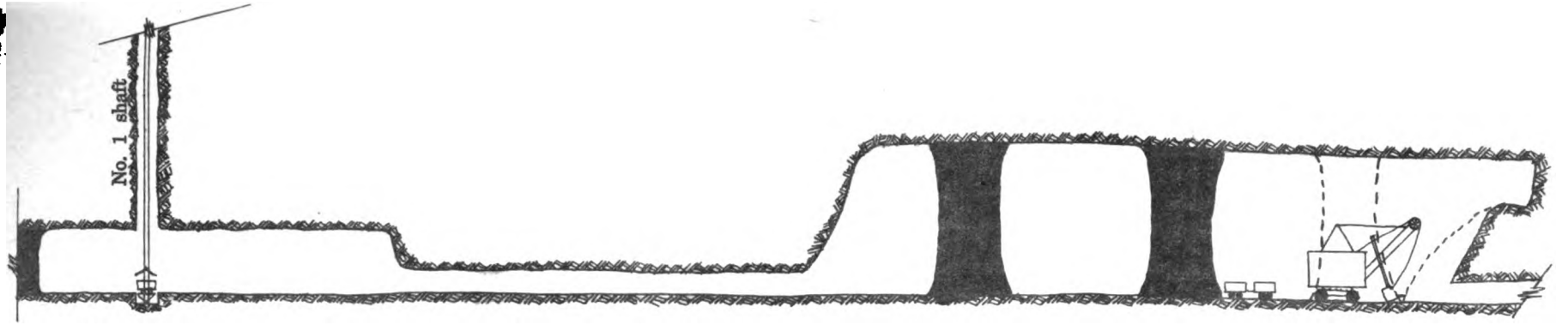
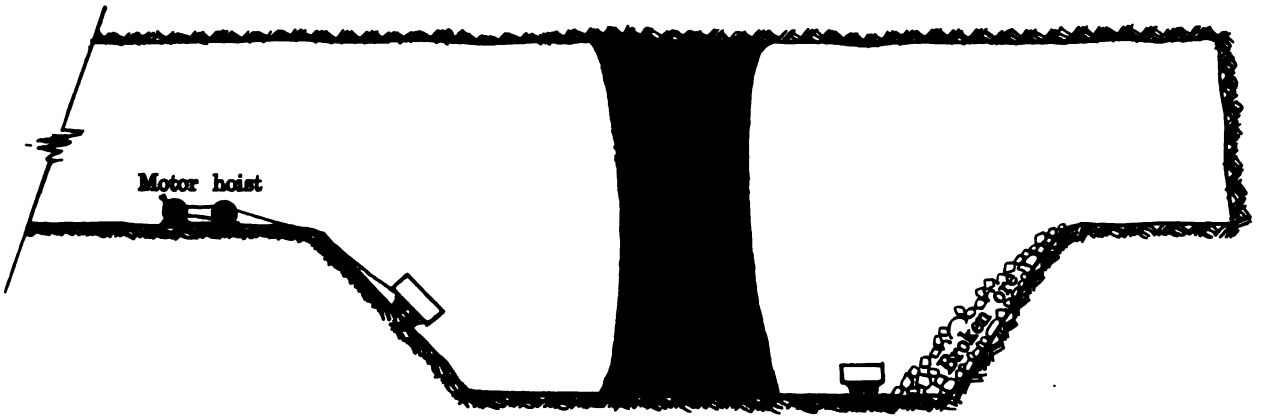


A. Section "*A*"–"*A*"



B. Section "*B*"–"*B*"

Figure 2. – Cross sections of stopes in active sections of mine

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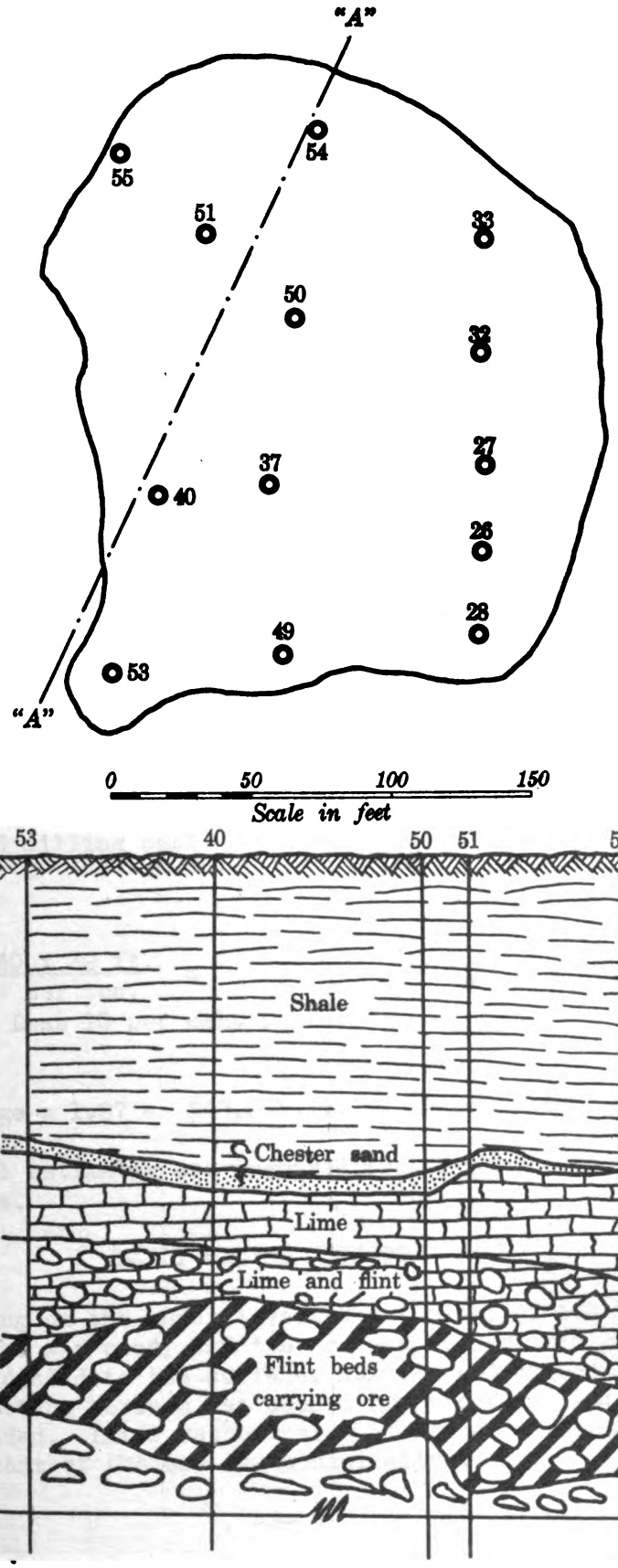

Figure 3.– Drill holes and ore body, projected on section at "A"–"A"

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Hole No.	Ore face	Height	Average ZnS	Assay PbS	Products ZnS	(Assay, ft.) PbS
26	180-200	20	5.70	- -	114.00	- -
27	150-200	50	4.40	- -	220.00	- -
28	172-188	16	4.05	- -	64.80	- -
32	165-200	35	4.04	- -	141.40	- -
33	180-205	25	6.14	- -	153.50	- -
37	155-175	20	7.55	2.00	151.00	40.00
40	154-218	64	7.34	- -	469.76	- -
49	170-205	35	3.91	- -	136.85	- -
50	165-205	40	10.40	- -	416.00	- -
51	172½-217	44½	21.40	- -	952.30	- -
53	170-187½	27½	15.30	1.02	420.75	28.05
54	190-220	30	9.25	1.19	277.50	35.70
55	190-200	10	2.14	- -	21.40	- -
		13)417			417(3539.26	103.75
		32			8.49	0.25

$40.00 per ton Zn concentrates
$90.00 per ton Pb concentrates used.

8.49 x 85 per cent extraction x $40.00 = $ 2.89 net
0.25 x 90 per cent extraction x $90.00 = .23
$ 3.12 value per ton

Less 8 per cent royalty .25
Mining and milling cost 1.60
1.85 1.85
$ 1.27 net value per ton

Area 17,040 x 32 ft. / 13 cu. ft. per ton. = 41,945
Less 10 per cent pillars 4,194.5
37,750.5 net tonnage

Net tonnage x 1.27 = $47,943.14, Value ore body.

Additional estimates are prepared from time to time as drilling progresses.

EARLY MINING METHODS

The early mining on the upper levels was typical of the district. The heading and stope system was used, and the ore was loaded into cans set on trucks; the loaded cans were hoisted to the surface, dumped, and immediately returned to the level. When the bottom horizon was opened up cars were installed instead of cans and were hand-loaded. Later mechanical shovels were introduced, and at present about 30 per cent of the ore is mechanically loaded.

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DEVELOPMENT SYSTEM

The mine is developed by a main operating shaft centrally located on the property and at the mill site, and the lower ore horizon, which is the ore now being mined, is developed from this shaft at the 300-foot level.. Development openings are carried in the ore wherever possible, but several "pull drifts" are drive to reach isolated ore bodies or to facilitate haulage between the active areas and the shaft.

There are two field shafts on the property, one of which is equipped with a double-deck cage for handling men and supplies and for ventilation. The other shaft was used for working the upper horizon and does not go down to the present level.

Development, as such, is very different from that in most metal-mining districts in the United States, except for the pull drifts. Development headings in ore are carried wide and at the top of the ore as a part of what in other districts would be stoping. Where the ore is not over 40 to 50 feet wide these headings are usually driven the full width of the ore, or the width between spotted pillars in wider ore bodies. The ore is stoped out between the heading and floor of the level, keeping the stope face at an angle of about 45°.

The local runs of ore below the main level are reached by short inclines, and inclines are resorted to for mining the ore in the north section of the mine which lies below the shaft level (fig. 2-B).

Shafts.- The mill shaft is 6 by 10 feet in the clear and has two compartments provided for hoisting self-dumping cages in balance. This shaft is concreted from the collar to a depth of 10 feet and cribbed to the rock. Below this point the shaft is untimbered except for the necessary supports for the cage guid

The man shaft is a two compartment shaft 6 by 12 feet in the clear. One compartment is used for a double-deck man cage, and the other, which is housed in is used as an airway and also contains a cage counterweight and pipeway and elect conduits. A force fan blows air down this compartment to the mine workings.

Pull Drifts.- Pull drifts are driven 7 by 7 feet to 8 by 10 feet and are untimbered. These drifts are usually driven on contract at an average price of $6 per foot. The contractor furnishes only the labor and explosives while the company furnishes all drilling equipment, air, and other supplies. The total co ranges from $10 to $12 per foot.

Figure 4, shows the drill round for pull drifts. Cut holes are drilled about 8 feet deep and all others about 7 feet, the usual round employing 4 cut holes, 2 relief holes, 3 roof holes, 3 "stope holes" (lifters), and 2 side holes or 14 holes in all. The holes are drilled with a medium-weight Leyner-type drif ing machine mounted on a 7-foot post or column and using $1\frac{1}{4}$-inch hollow round, lug-shank steel. The steel is made up in 2-foot changes with single 14° taper cross bits. The starters are made up with $2\frac{3}{4}$-inch gauge and the changes with 3/16 inch difference in gauge.

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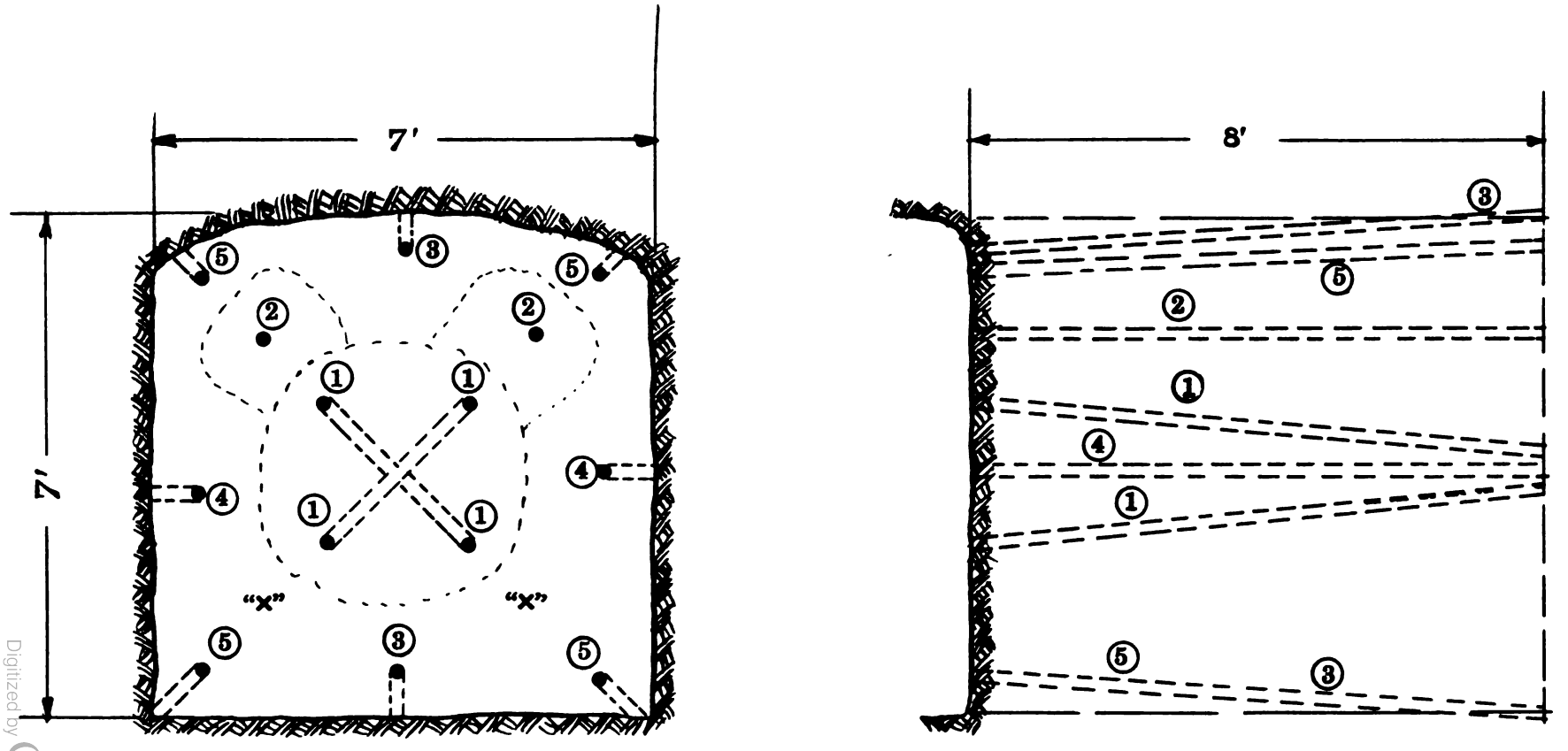

Figure 4. – Plan and profile of pull drift round. Circled numbers denote order of firing
Shaft round the same with the addition of two extra relief holes marked "X"

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Two men are employed on the drill, usually on night shift, and the drift is mucked on the opposite shift, ordinarily by one man. The average round is blasted with one box of 40 per cent gelatin powder using fuse and No. 8 caps for firing.

PRESENT MINING METHOD

The ore is mined by driving a heading next the roof and about 7 feet in height. The heading is usually carried three rounds or about 15 feet ahead of the stope which follows behind the heading. In low ore the stope is carried the full thickness of the ore. In high ore the stope is drilled and blasted with long flat stope holes at the bottom of the level as shown in Figure 5 with intermediate rows of "splitter" holes as required, depending upon the height of the stope. Stope and splitter holes are drilled up to a maximum of 18 feet in depth. The rows of holes are from 7 to 10 feet apart vertically with two or three holes about 10 feet apart in each row, the number depending on the width of the stope. The stope holes (bottom row of holes) are drilled and blasted first, leaving a vertical face from 7 to 10 feet high. The broken ore is only partly loaded out, enough being left against the face upon which to set up a tripod for drilling the splitter holes. Where more than one row of splitter holes is required, the lower row is drilled and blasted first, followed in order by the higher rows.

Figure 5, shows the methods used for driving headings and of drilling and blasting the stope or bench. Headings are drilled from a post and other holes from a tripod. The holes are loaded with 40 per cent ammonia powder and blasted with fuse and No. 8 caps. They are loaded to about two-thirds of the distance from the bottom and no stemming is employed.

The width of the stope is limited by the spacing of pillars for support of the roof. This distance is usually about 30 feet but varies from 25 to 45 feet. For the average stope three holes in a row are thus required for breaking the round.

There are three two stage compressors, one of 888 cubic feet capacity and two of 401 cubic feet of free air per minute and with a working pressure of 100 pounds per square inch at the compressor. The steel is handled in a round can and lowered and raised through a 16-inch borehole. The signal cord for the steel hoistman is run through another borehole.

The average number of tons of rock broken per machine shift during the period January 1 to May 1, 1929, was 64.2 tons.

LOADING AND TRAMMING

Two methods of loading are employed at this mine; hand-loading into cars and power-shovel loading into cars. Hand-loading is done on contract, the price being 38 to 41½ cents per car of 1½ tons each. For hand-loading, 2-inch planks are laid before blasting down to provide a smooth floor from which to shovel. The average performance of hand muckers in this mine for the first four months of 1929 was 24.9 tons per mucker shift.

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There are two power shovels in the mine. These shovels are of the boom-and-dipper full-revolving type which move by caterpillar traction and are operated by a single 25 hp. a.c. motor clutched to the swing hoist and crowd mechanism. The dipper has a capacity of 10 cubic feet.

Cars are brought to the shovel on a single track branching into two tracks behind the shovel. Two cars at a time are spotted by mule haulage, and cars are spotted and loaded on alternate tracks. The usual performance for the shovel is about 100 cars per shift, though as many as 116 cars or 175 cans have been loaded in four hours. The performance in mechanical loading during the first four months of 1929 averaged 49 tons per man-shift.

Haulage throughout the mine is by mules, of which there are eight in the mine at present. Mules are shortly to be replaced by a 5½-ton storage-battery locomotive on the main-line haulage.

The track gauge is 24 inches and 20-pound rails are used. The cars are equipped with roller bearings.

There are three inclines in the mine over which cars are lowered and hoisted by small electrically driven hoists. One slope is 300 feet long and the other about 30 feet long. The former is on a 7 per cent grade and the latter is on a 45° slope. Only one car per trip is handled on these inclines.

The cars are caged at the shaft bottom by hand. There is a double track at each side of the shaft and a single runaround track around one end of the shaft. The loaded cars are run on from one side and bump the empties off the cage; the empty cars are released by a foot treadle operated by a man on the empty car side. The oncoming loaded car strikes a latch which throws the cage stops into the stop position again.

PERCENTAGE OF EXTRACTION

From 15 to 18 per cent of the area mined is left for pillars. The greater number of these are ore pillars and will eventually be mined. The leaner ones will be left. As the total height of the face is more or less mineralized, there can be no precise factor determined as to the dilution of ore by waste. All rock is run through the mill with no waste boulders discarded. This of course forces the richer ore bodies to furnish the bulk of the tonnage. The leaner areas furnish only that tonnage needed to keep the mill capacity at its critical efficienc

WAGE, CONTRACT AND BONUS SYSTEM

Labor is based on an eight-hour day. Muckers are paid from 38 to 41½ cen per car according to the "layout" and length of haul to the "lay-by" or gathering track. This price fluctuates up or down with the ore market, but is based on a price of $40 per ton of concentrates. For every $5 increase, shift wages are automatically increased 25 cents per day and muckers 1½ cents per car. On a downward market all wages are correspondingly decreased. This, however, is the gener practice throughout the district. The average wage scale at this mine based on $40 per ton concentrates is as follows:

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Machine operators	$ 4.75
Trammers	4.00
Machine helpers	4.25
Blacksmiths	6.00
Hoistmen	4.50
Powdermen	5.00
Roof trimmers	4.25
Hookers and cagers	4.00
Shovel operators	5.00
Trackmen	4.50

VENTILATION

The ventilation in the mine is by force draft supplied by a large fan at No. 2 shaft. An individual motor-driven blower is set at the west portal of the long pull drift, which runs in a southeasterly direction, and air is supplied through 850 feet of galvanized sheet iron tubing of 16-inch diameter. Occasionally, as in raises, air is supplied through flexible tubing by small individual motor-driven blowers. Often churn-drill holes are equipped with blowers on the surface by which a blast of air is forced into the workings.

FIRE HAZARDS

As there is no timbering in the workings, nor are there explosive gases, the fire hazard is negligible. In case of fire at any of the surface plants, there are one or more means of egress through different shafts or other properties, so that the men are in little or no danger.

SAFETY METHODS

The company maintains a full-time safety engineer who makes regular and systematic examinations of all workings and equipment and is empowered to enforce any safety measures he may deem necessary. An excellent spirit of cooperation exists between the men and the safety engineer, so that lost-time accidents are rare and minor accidents infrequent.

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TABLE 1.- SUMMARY OF COSTS

Barr mine. Period covered: January to April, 1929.

Tons ore hoisted during period: 45,344
Tons ore hand-loaded: 33,306
Tons ore mechanically loaded: 12,038

Mining method: Open stopes with pillar support.

Underground Costs per Ton of Ore Hoisted

	Labor	Super-vision	Compressed air drills and steel[1]	Power	Explo-sives	Other supplies	Total
Development[2]	- -	- -	- -	- -	- -	- -	- -
Mining	$.3101	- -	$.0661	$.0138	$.1033	$.0508	$.544
Transportation[3]	.1372	- -	- -	.0338	- -	.0453	.216
General underground expense	.0239	.0258	- -	- -	- -	.0196	.069
Surface expense (applicable to underground)	.0315	- -	- -	- -	- -	- -	.031
Total	.5027	.0258	.0661	.0476	.1033	.1162	.866

1 Includes power for compressing air.
2 No development in rock during period.
3 Includes mule and locomotive haulage, and hoisting.

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TABLE 2.- SUMMARY OF COSTS IN UNITS OF LABOR, POWER, AND SUPPLIES

Barr mine. Period covered: January to April, 1929.

Tons ore hoisted during period: 45,344
Tons ore hand-loaded: 33,306
Tons ore mechanically loaded: 12,038

Mining method: Open stopes with pillar support.

A. Labor (man-hours per ton):

		Man hours per ton
Breaking (drilling, blasting, and trimming)		.223
Mucking (hand and mechanical)		.279
Mucking (hand only)	.321	
Mucking (mechanical only)	.163	
Haulage and hoisting		.305
Supervision		.030
General		.051
Total man hours per ton underground		.888
Average tons per man-shift underground		9.024
Average tons per man-shift surface labor		192.3
Labor, percentage of total cost		55.5

B. Power and supplies per ton:

Explosives (lbs. per ton), 40 per cent ammonia		.805
Power: Air compression, kw.h. per ton	2.16	
Hoisting, kw.h. per ton	2.79	
Ventilation, power loading, and haulage	1.14	
Total kw.h. per ton underground		6.09
Other supplies in percentage of total power and supplies	47.0	
Power, materials, and supplies, percentage of total underground cost	44.6	

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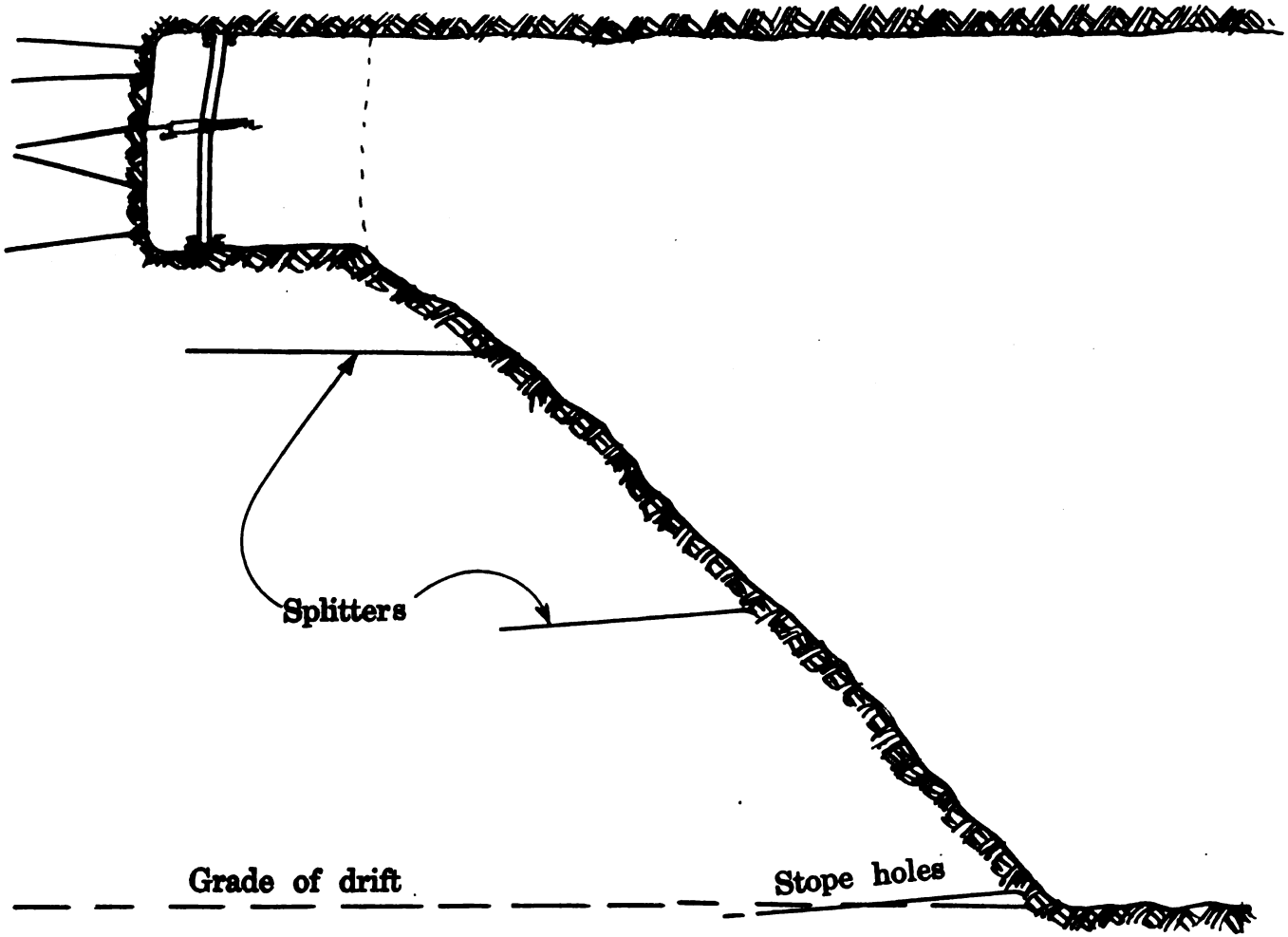

Figure 5. – Showing method of advancing stopes to headings by "splitter holes"

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